DATA ON TRAFFIC ACCIDENTS INVOLVING FIRES AND EXPLOSIONS

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Abstract. Transportation of hazardous materials poses the risk of major accidents on road and rail. Such accidents are usually triggered by a traffic accident on road and rail and occur as fires, explosions and releases of hazardous materials. The present paper takes a look on data related to traffic accidents which end up in fires and explosions. Data sources are described and an initial processing of this data is carried out. Results of data processing are represented as relative probabilities of occurrence of fire and explosion accidents. The study detects a variety of accident scenarios and presents a visualisation of these scenarios by means of an event tree. The findings of the study have the prospect of an application to the assessment of risk in transport infrastructure.

Keywords: explosion, fire, transportation, release, accident, BLEVE.

Introduction

Every day large amounts of hazardous materials are transported by road tanks. Accidents of these vehicles pose serious risk to road traffic and roadside territory (Planas-Cuchi et al. 2004; Oggero et al. 2006). Land transport is very important for a country’s economy because it is used for the mobility of both goods and persons. Accidents may represent a serious risk for the population and they often cause water, air and soil to become polluted. In fact, several surveys have indicated an increasing trend in the frequency of accidents in the transportation of hazardous materials. This paper aims to provide an updated survey on the situation in this field, by analysing the accidents that occur during the transport of dangerous goods by road and rail: their causes, consequences, materials involved, severity and frequency, and drawing some conclusions on the measures to be taken in order to reduce this frequency.

Data collections

In earlier year, availability of data was a common problem in most developing countries (Jacobs and Sayer 1983; Mekky 1984; Al-Saif 1997). One important piece of information in safety-related studies was traffic exposure, which was not available. Therefore, this study was limited by not having such data. In traffic police reports, lack of accurate identification of accident locations was common; the accident location was typically identified only as an intersection (T or four-leg and whether signalized or not) or road section, and most of the time the names of the streets were not included. By 2000, the IRTAD contains retrospective data since 1965 for 30 countries. Only statistics about fatalities was homogenous with the use of the international definition or the application of national coefficients in order to estimate fatalities within 30 days for all the countries. The use of other statistics must were accompanied by a careful reading of the definitions to perform honest comparisons. For instance a slightly injured user was defined as needing medical treatment without hospitalisation (Portugal), needing medical treatment with or without hospitalisation (France), needing medical treatment up to 30 days (Japan), whose life was not in danger (Greece), with minor injury such as sprains, bruises or cuts which do not necessarily require roadside attention (Great Britain).

In recent years, EU countries have many databases for accidents collection. CARE is data bank on road traffic accidents in Europe. Main sources for this database is: traffic police accident reports, observations at sites additional evidence from police officers or witnesses interviews with road users involved clinical assessment of injuries technical inspection of damage. Such accident databases are needed at EU level to describe the current state of transport safety across the European Union, to help define target levels of safety for each of the transport modes and to adopt a data-led systems approach in defining strategies. The process of creating a range of common data sources necessary for the development began in 1993. Has been achieved, especially for road transport, but for other modes basic kinds of data are lacking on an EU-level. International Road Traffic and Accident Database (IRTAD) has been maintained by BASt (Germany).
Moreover almost all West Europe Counties have their accident databases.

The Major Hazard Incidents Data Service (MHIDAS), which was used to carry out the present study, is managed by the SRD, which belongs to the UK Health and Safety Executive. The database contains incidents from over 95 countries and all the information in it is taken from public-domain information sources. The database, which is continuously being updated, was started in the early 1980s, although it contains references to incidents that took place in the early years of the 20th century. The July Version (MHIDAS 2004), in which there are 12,369 records of accidents, was used for this study.

One of the limitations of this database is the fact that one accident may have more than one record (e.g. 1055A, 1055B and 1055C) if there is more than one cause, more than one incident type or various substances were involved. This problem was solved by creating a new database (based on Microsoft Access). Thus, the same accident can only be selected once and various searches can be made quickly and without repetitions. A group of only new incidents (coming from different sources) can be obtained. In order to identify the records that are specifically related to road and railway accidents, the search criteria shown in Fig. 1 were used and implemented in a computer code (from MHIDAS to the Access database). This is the same procedure as that used by A. Ronza et al. (2004).

Several incidents that did not occur on roads or railways were automatically included in the selection and it was therefore necessary to check each record to eliminate errors. Accidents occurring during loading/unloading operations (which are relatively frequent) and in parking lots, ports, factories and depots were not considered. The fields used in this study are the same as those of MHIDAS. Moreover, for each accident more information was drawn up and placed in new additional fields: Source (name of the database or other sources used), Road/Rail, Country, Type of road, Initial event (sequence of events that led to the accident), Class (explosive, toxic, flammable, etc., in accordance with the European classification system), Vehicle type, Phenomena (time sequence of phenomena after the accident) and Pollution (type of pollution eventually caused).

After a study were found the following agreements:

1. The incident type (IT) field classifies each accident under four basic categories: fire, release, explosion and gas cloud. Each accident may belong to one or more of these types. Present information is often incomplete or even lacking. That is why we can get only four types of IT.

2. MHIDAS does not contain a field that explains which initial event causes the incident. The general cause (GC) and specific cause (SC) fields do not include a time sequence of events, so a new field, Initial event, was added, replacing the previous two. The main problem is often one of establishing the correct succession of events: for example, the abstract of the famous accident in Mississauga in Canada reports Series of explosions/BLEVEs followed derailment of LPG tankcars. Missiles thrown 667 m. Fire threatened derailed chlorine tanker which leaked for 51 h while fire burned + further 48 h until hole plugged. Mass evacuation of area organised. The GC field in the database states External–Impact–Mechanical, while the SC field states ExtnlFire–Overheat–Railacc, so it is possible to establish some sort of sequence (such as Impact, Railacc, External, ExtnlFire, Mechanical and Overheat) although one cannot be 100% sure. For this reason, an Internet search for further information was sometimes required.

3. The database often proves to be quite vague when it splits up the different substances. Generic categories like “oil” or “chemicals” often appear in the Material name field. For this reason, the substances were grouped according to their names as reported by MHIDAS (Oggero et al. 2006).

Characteristics of accidents

In recent years, all authors who have analysed frequency of accidents which was as a function of time for chemical plants, transportation of hazardous materials or maritime transportation, have found what the number of accidents significant increase. For the large number of accidents processed in the present analysis, this trend is again found.

The function of time as distribution of the accidents is plotted in Fig. 1. It can be observed that there is a gradual increase with a significant rise in the period 1981–2000. This increase is governed by two factors:

1. The increase in land transport (road and rail)
2. Better accidents information accessing.
The location of the accidents was studied from three points of view: the country in which the accident happened, the kind of land traffic (rail or road) and the type of thoroughfare. The accidents were divided into three categories according to the place where they occurred: (1) United States, Canada, Australia, Japan, New Zealand and Norway, (2) The European Union, (3) The rest of the world.

More than half of the registered accidents occurred in the first category. Although obviously the greatest volume of land traffic of hazardous substances is in more industrialised countries, there probably the origin of the data base have more intensive and complete search. Moreover, was found that the USA and UK have the highest quantity of accidents during the transport of hazardous materials by rail or road, for instance the USA 47% and UK 30% of 1932 records. Therefore, the quantity of accidents does not rely only on country total area.

From the total number of accidents (1932) were found two kinds of traffic type with large number of accidents: 37% occurred on railways and 63% on roads. Of the accidents occurring on roads for which the type of road is known, the most frequent category is highways (81.4%), followed by level crossings and minor roads (both with 7.6%), and finally tunnels (3.3%) (Fig. 2).

The accidents that occurred in railway tunnels were mostly caused by derailment (six cases). The accidents that occurred in road tunnels were mostly caused by road accidents (four cases); in three of them there were fatalities. In all of the tunnel accidents involving a fire, extinguishing the fire was quite difficult because of the smoke, and in some cases the fire burnt for several days (Oggero et al., 2006). The database contains 13 accidents, which occurred inside tunnels. If the one is not considered, then seven occurred in rail transport and five in road transport.

Methods of quantitative risk assessment a BLEVE accident of a road tank is a low-probability initiating event. It can be internal or external event with respect to exposed installation (Kumamoto, 2007; Garrick, 2008). QRA can be focused on a specific random damage event $D$, for instance, loss of containment of a tank or rupture of a pipeline due to mechanical and thermal actions of BLEVE. In this case the frequency of $D$ can be expressed as a product of frequency of transportation (mission frequency) $F(M)$ and three conditional probabilities which relate $M$ to $D$:

$$F(D) = F(M) \cdot P(A\mid M) \cdot P(B\mid A) \cdot P(D\mid B),$$

where $A$ is the random event of a road accident, in which the road tank will be involved, and $B$ is the random event of BLEVE.

The estimation of the conditional damage probability $P(D\mid B)$ requires to assess mechanical and thermal effects of BLEVE. If these effects are grouped into a vector $y$,
the damage probability can be expressed as follows (Vaidogas and Juocevičius 2009):

\[
P(D \mid B) = \int_{\mathbb{R}} P(D \mid y)f(y)dy = \int_{\mathbb{R}} P(D \mid \psi(x))f(x)dx
\]

where \(P(D \mid y)\) is the fragility function relating the probability of \(D\) to \(y\); \(x\) is the vector of characteristics of BLEVE accident; \(\psi(x)\) is the vector-function which relates \(x\) to \(y\) (i.e., \(y = \psi(x)\)); and \(f(x)\) and \(f(y)\) are the joint probability density functions of \(x\) and \(y\), respectively.

The density \(f(x)\) expresses uncertainties in those characteristics of BLEVE accident which serve as input in the model \(\psi(x)\). This density can be specified by means of two basic approaches to QRA known as classical Bayesian approach and predictive, epistemic approach (Apeland et al. 2002; Aven 2003).

The accidents are classified into four different types: release, explosion, fire and gas cloud. The analysis shows that 78% of cases of accident are releases are, followed by fires in 28%, explosions in 14%, and gas clouds in only 6%.

The most of accidents starts in hazard materials release, can cause an explosion or might give rise to an explosion followed by a fire. For instance, an accident in the Viareggio has a few models of event:

- the release of liquid propane from the crack in the tank car;
- the flash of the liquid jet in the atmosphere;
- the spreading and boiling of the LPG pool on the ballast;
- the dispersion of vapors emitted from the tank car and of those evaporated by the pool;
- the dilution of the gas cloud in presence of obstacles such as the permeable fence at the railroad borders, and the houses on the cloud path;
- the ignition of gas pockets inside the houses and the magnitude of the consequent explosion;

![Fig. 3. A photo of a road tank accident which escalated into a fire](image)

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![Fig. 4. General event tree and relative probabilities of occurrence](image)
the ignition of the liquid pool, and the consequent pool fire (Manca et al. 2010). It is seen, that one event may have all categories of accident types.

Fig. 4 was drawn up thanks to the availability of data for 1573 accidents, while for the rest the incident sequence was not specified. The figures in brackets represent the probability of occurrence in comparison with the level immediately above that (i.e. obtained from the ratio of the number of accidents to the number of accidents at the higher level). The figures at the end of each branch show the overall probability of occurrence of each specific accident, what depend from set events. Accidents tree shows that:

- Only 1 out of every 4.3 fires leads to an explosion.
- 1 out of every 8 releases gives rise to a fire and 1 out of every 16 release–fire events causes an explosion.
- 1.5% cases of release evoke immediate explosions.
- 1 out of every 3.6 accidents leads to a fire and, more specifically.
  - 1 out of every 15 accidents leads to fire–explosion.

Comparing these results with the ones obtained by A. Ronza et al. (2003) in a previous study of accidents occurring in ports, a similar trend concerning releases and fires can be observed. However, the number of accidents leading to an explosion is far greater in ports than in land traffic.

Accident initiators

Eight types of possible causes were taken into consideration: mechanical failure, impact failure, the human factor, instrumental failure, services failure, violent reaction, external events and upset process conditions. It should be mentioned that 9% of the accidents were not classified into any of these general causes and were therefore not included in this analysis.

According to the analysis, 73.5% of accidents in road and rail transport were caused by an impact or collision between vehicles, derailment of trains or lorries crashing, etc. (an origin which often implies human error). They were followed by types of mechanical failure, external events and human factors, which together add up to more than 18%. The percentages for the remaining causes show that the latter are quite relevant (8%), so the general category of “Others” was created.

All accidents may be involved by specific cause, but the most important is the general cause. For the majority of general causes, one or several specific causes can be defined. These data agree with the information published by G. Tiemessen et al. (1998), who found that overturning of a road tanker followed by a release was the most significant transport accident type in The Netherlands.

Fig. 5. A photo of a railway tank accident that invoke explosion in Bailystok

The main cause of mechanical failure was valves at 29%. The most common external events were external fires (44%), sabotage (9%) and explosions (8%). Finally, in considering human factors, the most significant ones were general operations at 35%, and procedures at 11%. In this case the “Others” percentage is also quite high because there are a great variety of specific causes.

Of the total of 1932 accidents the most frequent initial event (general cause + specific cause) is Impact–Roadaccident at 30%, followed by Impact–Railaccident at 25% and Impact–Vehicle at 13%.

Conclusions

The analysis of data bases of 1932 accidents carried out that frequency has an upward trend. In fact, it is well known that the transportation of hazardous materials poses the risk of major accidents on road and rail. The accidents causes increased significantly, due to transported tonnes km/year increasing, and this is certainly one of the reasons for this situation. However, the information about accidents found, 37% occurred on railways and 63% on roads.

The study detects a variety of accident scenarios and presents a visualisation of these scenarios by means of an event tree. According to the event tree, the most frequent phenomenon without further consequences is release (62% of) cases, followed by fire, which occurred in almost 12% of cases. In general, release–fire sequences account for 9.5% of cases, while release–fire–explosion sequences account for 0.6%. Fires (all types and sequences) are present in 29% of cases. However, as one
phenomenon was often followed by another, the following information is probably more significant: the most frequent sequence is a release followed by a fire (12.7%), a gas cloud (7.7%) and an explosion (1.8%).

The most frequent initiating event of accidents is impact, with 73.5% of the accidents being due to collisions. More than half of the accidents did not cause any fatalities.

Overall, the study presented here reveals a worrying trend in the frequency of accidents. There is clearly a need to improve safety measures in the various aspects of land transport to tackle the growing frequency detected in the occurrence of accidents. It should be emphasised again that 73.5% of accidents were initiated by collisions (i.e. traffic accidents) and that most accidents in tunnels were caused by derailment (rail) and by road accidents. Therefore, besides general aspects, such as maintenance of trains and lorries, better road conditions, etc., training of professional people involved in this transportation seems to be of major importance.

References


DUOMENYS APIE GAISRUS IR SPROGIMUS KELIUOSE IR GELEŽINKELIUOSE

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Santrauka


Reikšminiai žodžiai: sprogimas, gaisras, išsiliejimas, transportavimas, avarija, BLEVE.